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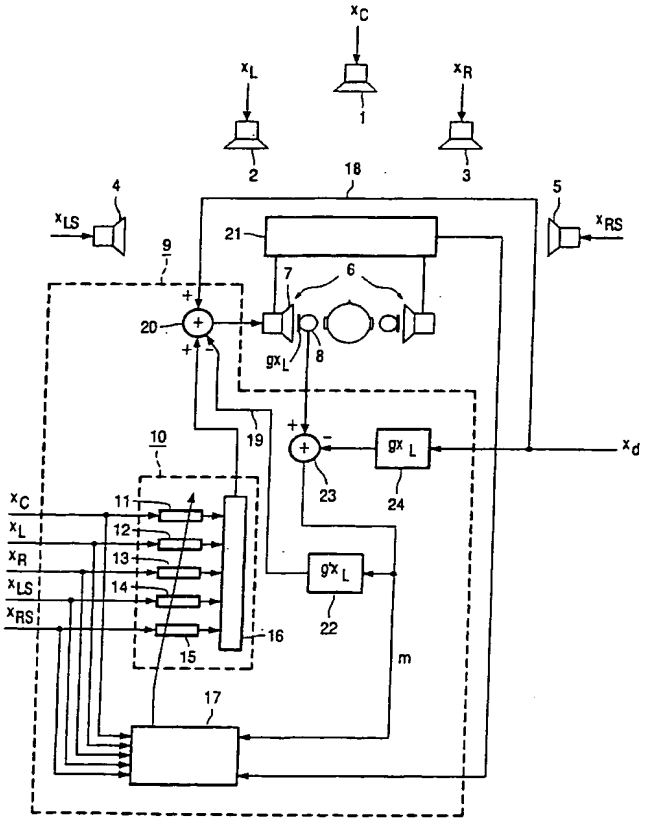
(54) Title: METHOD FOR CANCELING UNWANTED LOUDSPEAKER SIGNALS



(57) Abstract: In a method for canceling unwanted signals from at least one external sound source, such as a loudspeaker, by means of headphones provided with microphones, at least known sound signals from the at least one external sound source are compensated by anti-phase sound signals. These sound signals simulate the at least known sound signals from said at least one external sound source in anti-phase. Said anti-phase sound signals are generated in the headphones in response to signals derived from audio input signals of the at least one external sound source in a filter device which is controlled by the resulting microphone signals.

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Method for canceling unwanted loudspeaker signals

The invention relates to a method for canceling unwanted signals from at least one external sound source, such as a loudspeaker, by means of headphones provided with microphones.

From the international patent application WO 94/30029 a noise cancellation system for headphones is known. In this document a noise cancellation system for canceling unknown low frequency and high frequency, rapidly changing noise is described wherein microphones, included in the headphones, pick up sound signals in the headphones. Based on signals from the microphones the unknown noise is estimated whereafter anti-noise signals are generated by means of a noise cancellation algorithm. These anti-noise signals, supplied to the headphones, reduce the noise. The disadvantage of this method is that all sound signals are suppressed to some extend.

When, for example, someone wants to read a newspaper in quiet, while at the same time someone else is watching television, the application of noise cancellation headphones of the type described above could be the basis for a solution to suppress sound signals from the loudspeakers of the television. However in that case, instead of unknown noise signals, we have known signals which have to be suppressed; an estimation of the noise is not necessary. When, such noise cancellation systems of the above described type are used, the disadvantage mentioned above, i.e. a limited performance, will still be valid. Further, in such systems also other sounds-like conversations in the room, which are not coming from the loudspeakers will be suppressed too.

The purpose of the invention is to find a method for cancellation unwanted signals from at least one external sound source, in which the disadvantages of the above noise cancellation systems are avoided or at least mitigated.

Therefore, according to the invention, there is provided a method for canceling unwanted signals from at least one external sound source, such as a loudspeaker, by means of headphones provided with microphones, wherein at least known sound signals from the at least one external sound source are compensated by sound signals, simulating in anti-phase the at least known sound signals from said at least one external sound source, said anti-phase sound signals being generated in the headphones in response to signals derived from input

audio signals of the at least one external sound source in a filter device which is controlled by the resulting microphone signals. The advantage of this method is that, because the unwanted signals are already known, no estimation of the noise, i.e. the unwanted signals, is necessary, the cancellation method according to the invention is much easier, while the disadvantages of the cancellation of unknown noise, as indicated above, is avoided.

In a first embodiment, during initialization, the characteristics of the filter device are computed by means of a sound source simulation algorithm, which algorithm controls the characteristics of the filter device such that the signals of the microphones are minimized or become substantially zero.

After this initialization, the filter device is fixed. Although this embodiment is relatively simple to implement, the cancellation of the unwanted sound signals will only work if the headphones listener does not move his or her head.

Therefore in a preferred, second embodiment, to obtain a set of different filter characteristics, the process of computing is performed on various places in the direct neighborhood of the listening position, while during sound reproduction one set of said filter characteristics is selected by means of the algorithm, depending on the position of the head of the person who wears the headphones, which position is indicated by a head tracker. It may be noted that head trackers are known per se, for example from European patent application EP-A-0 762 803.

The method of suppression of known unwanted signals may be combined with a reducing of unknown unwanted, particularly environmental noise signals. In that case the method according to the invention is further characterized in that, while known unwanted signals from the at least one external sound source are suppressed, unknown unwanted, particularly environmental noise signals are reduced by deriving from the microphone signals further signals which, after being converted into sound signals represent in anti-phase said unknown unwanted signals.

It is desired that the person wearing the headphones may listen to his or her own music, while the unwanted signals from the at least one external sound source are suppressed. Therefore, further according to the invention, the method is characterized in that, while unwanted signals from the at least one external sound source are suppressed, a further audio input signal is supplied to the headphones and a correction signal is applied to the microphone signal, said correction signal being derived from said further audio input signal such that the corrected microphone signals are still minimized or become still substantially zero.

The invention also relates to a sound reproducing system, for applying the method described above, comprising headphones with sound generating means and with microphones, and control means, the control means being provided with a filter device to control the sound signal generated by said sound generating means to simulate at least one external sound source in response to a known audio input signal and with regulation means to regulate said filter device such that the signals supplied by the microphones and fed to the control means are minimized or substantially zero when said known audio input signal is also supplied to said at least one external sound source. Particularly the control means comprise a sound source simulation algorithm to determine one or more sets of filter characteristics, each set of filter characteristic corresponding with one position of the head of the person who wears the headphones. In case more sets of filter characteristics are established, a head tracker is provided by means of which the position of the head of the person who wears the headphones can be determined. The international patent application WO 01/49066 shows a similar sound reproducing system. However, the control device works different; the system in said international patent application is operable in the following two phases: In a first phase the filter device is adjusted in such a manner that by means of an audio input signal supplied to the filter device a signal is generated in the sound generating means which compensates the audio input signal. Then, in a second phase the at least one external sound source is made inoperative, so that the sound generating means provide for a sound reproduction through the microphones which simulates the at least one external sound source. The first phase is introduced for measuring the transfer functions from external sound sources (loudspeakers) to the microphones in headphones inside a listener ears. The sound is than generated by passing the audio signals through the filter means, adjusted to these transfer functions, and reproducing the resulting sound through the headphones.

As the suppression of known unwanted sound signals may be combined with a reducing of unknown unwanted, particularly environmental noise sound signals, the control means can further comprise combination means and correction means to provide, in response to the microphone signals, for signals, which, supplied to the sound generating means, reduce unknown unwanted, particularly environmental noise signals, the transfer function of the correction means being such that the product of the latter transfer function with the transfer function of the sound generating means to the microphones is about 1 (one) over a certain frequency range.

To make it possible that the person wearing the headphones may listen to his or her own music, while the unwanted signals from the at least one external sound source are

suppressed, the control means may further comprise combination means and further correction means to insert a further sound signal to the sound generating means and to correct the microphone signal with a correction signal derived from said further audio input signal, the transfer function of the correction means substantially being the same as the transfer function of the sound generating means to the microphones.

The invention further relates to an algorithm, applied in the method described above, for processing the above filter device.

The invention will be apparent from and elucidated with reference to the example as described in the following and to the accompanying drawing, which shows in Fig. 1 schematically the sound reproducing system according to the invention.

In the example described there are five external sound sources in the form of loudspeakers 1-5, viz. for an audio center channel, left and right channels and surround channels. The audio input signals for these loudspeakers are indicated by respectively x_C, x_L, x_R, x_{Ls} and x_{Rs}, in general x_i. In the center of the figure the head of a person is indicated; this person carries headphones 6 with sound generating means 7 and microphones 8. The processing according to the invention is only considered for the left ear of said person as the processing for the right ear is likewise. The microphone 8 supplies a microphone signal m in response to sound signals from the loudspeakers 1-5 and from the sound generating means 7. The input signal of the sound generating means 7 is supplied by control means 9. These control means comprise a filter device 10 with filters 11-15 and combination means 16, and regulating means 17. The transfer function of the filters 11-15 is indicated by respectively $h_{C,L}$, $h_{L,L}$, $h_{R,L}$, $h_{Ls,L}$ and $h_{Rs,L}$, in general $h_{i,L}$. The input signals of these filters are chosen for sake of simplicity to be the same as the input signals for the loudspeakers, viz. x_C, x_L, x_R, x_{Ls} and x_{Rs} respectively. The filter device 10 supplies a signal $\Sigma x_i.h_{i,L}$ to the sound generating means 7. The "point" in this and following mathematical expressions means a multiplication in the frequency domain and a convolution in the time domain of the relevant signals and functions.

Apart from the signal supplied to the sound generating means 7 via lines 18 and 19 and the combination means 20, which will be discussed later on, the output signal of the sound generating means 7 established by the microphone 8 can be represented by

$gx_L.\Sigma\ x_i.h_{i,L}$ with gx_L the transfer function of the sound generating means 7 to the left microphone 8. When the transfer functions from the loudspeakers 1-5 to the left microphone 8 are represented by $gx_{C,L}$, $gx_{L,L}$, $gx_{R,L}$, $gx_{Ls,L}$ and $gx_{Rs,L}$, in general $gx_{i,L}$, than the signal m from the left microphone 8 can be represented by :

$m = \Sigma\ x_i.[\ h_{i,L}.\ gx_L + gx_{i,L}]$.

The filters characteristics are computed and regulated by means of a sound source simulation algorithm in the regulation means such that m is minimized, with m=0 in the ideal situation. This means that, after initialization, the signals from the sound generating means 7 are equal to the signals from the loudspeakers, but in anti-phase, and thus that by means of said filters the sound signals from the loudspeakers are simulated.

When the filters 11-15 are adjusted, during initialization, in such a way that the microphone signal m is minimized the desired cancellation of the loudspeaker signals will be obtained. In that case the transfer functions of the filters 11-15: $h_{i,L} = -gx_{i,L} / gx_L$, are fixed.

When the person wearing the headphones moves or takes another location, the transfer functions from the loudspeakers 1-5 to the microphones change, so that the transfer functions of the filters 11-15 do not correspond any longer with forms with m minimized. Although in that case the initialization can be repeated for the new position, it may be an advantage when in the initialization phase for a number of head positions and/or neighboring positions a set of filter characteristics is established and stored in the regulation means 17. By means of a known head tracker 21, preferably mounted on the headphones 6 the position of the head of the person wearing the headphones can be established and a specific set of filter characteristics can be selected therewith. In some cases, for example, when the tracking rate of the head tracker is not sufficient, it is of advantage that a filter with fixed filter characteristics is used or with filter characteristics which, each time the head of the person wearing the headphones moves, are gauged (updated) continuously.

When the suppression of known unwanted sound signals will be combined with a reducing of unknown unwanted sound signals, such as environmental noise signals, the microphone signal may be supplied to correction means 22, while the output signal of said correction means 22 is supplied to the sound generating means 7 via the line 19 and the combination means 20, wherein said output signals are combined with the signals from the filter device 10. The transfer function of the correction means 22, viz. $g'x_L$, is such that the product of the latter transfer function with the transfer function of the sound generating means 7 to the microphones 8 is about 1 (one) over a certain frequency range:

$gx_L.\ g'x_L \approx 1$.

The sound generating means 7 reproduce sound signals which approach the unknown unwanted sound signals, but in anti-phase, which leads to a reduction of said unknown unwanted sound signals.

When the person wearing the headphones likes to listen to some music, a desired audio signal x_d thereof may be supplied to the combination means 20 via the line 18 and added to the signals from the filter device 10. However, in that case in the expression for m, a term $x_d.gx_L$ is introduced. In order to compensate for this term in the connection between the microphone 8 and the regulation device 17 combination means 23 are inserted. In these combination means 23 the value of the microphone signal is diminished with a value $x_d.gx_L$, derived from further correction means 24. The transfer function of these further correction means 24 is substantially the same as the transfer function from the sound generating means 7 to the microphone 8.

By means of the above described sound reproducing system, after initialization, known unwanted signals from the loudspeakers are suppressed, independent of the position where the person, carrying the headphones, is located in the room where the loudspeakers are arranged, while further optionally unknown unwanted sound signals can be reduced.

The method and the embodiment described above may be realized by an algorithm, at least part of which may be in the form of a computer program capable of running on signal processing means in an audio apparatus or cooperating with an audio apparatus comprising the sound reproducing system according to the invention. In so far part of the figure shows units to perform certain programmable functions, these units can be considered as subparts of the computer program.

It may be noted that, although not indicated in the figure, corresponding control means are provided to suppress unwanted signals in the right ear.

The invention is not restricted to the described embodiment. Modifications are possible. For example, the number of external sound sources is irrelevant. The audio input signals applied to the filters need not to be equal to the audio input signals of the loudspeakers; it is sufficient when there is a relation between both audio input signals.

CLAIMS:

1. Method for canceling unwanted signals from at least one external sound source, such as a loudspeaker, by means of headphones provided with microphones, wherein at least known sound signals from the at least one external sound source are compensated by sound signals, simulating in anti-phase the at least known sound signals from said at least one external sound source, said anti-phase sound signals being generated in the headphones in response to signals derived from audio input signals of the at least one external sound source in a filter device which is controlled by the resulting microphone signals.

2. Method for canceling unwanted signals from at least one external sound source, according to claim 1, wherein, during initialization, the characteristics of the filter device are computed by means of a sound source simulation algorithm, which algorithm controls the characteristics such that the signals of the microphones are minimized or become substantially zero.

3. Method for canceling unwanted signals from at least one external sound source, according to claim 2, wherein, to obtain a set of different filter characteristics, the process of computing is performed on various places in the direct neighborhood of the listening position, while during sound reproduction one set of said filter characteristics is chosen by means of the algorithm, depending on the position of the head of the person who carries the headphones, which position is indicated by a head tracker.

4. Method for canceling unwanted signals according to anyone of the preceding claims, characterized in that, while known unwanted signals from the at least one external sound source are suppressed, unknown unwanted, particularly environmental noise signals are reduced by deriving from the microphone signals further signals which, after being converted into sound signals represent in anti-phase said unknown unwanted signals.

5. Method for canceling unwanted signals from at least one external sound source, according to anyone of the preceding claims, characterized in that, while unwanted

signals from the at least one external sound source are suppressed, a further audio input signal is supplied to the headphones and a correction signal is applied to the microphone signal, said correction signal being derived from said further audio input signal such that the corrected microphone signals are still minimized or become still substantially zero.

6. Sound reproducing system, for applying the method of any one of the preceding claims, comprising headphones with sound generating means and with microphones, and control means, the control means being provided with a filter device to control the sound signal generated by said sound generating means to simulate at least one external sound source in response to a known audio input signal and with regulation means to regulate said filter device such that the signals supplied by the microphones and fed to the control means are minimized or substantially zero when said known audio input signal is also supplied to said at least one external sound source.

7. Sound reproducing system, according to claim 6, characterized in that the control means comprises a sound source simulation algorithm to determine one or more sets of filter characteristics, each set of filter characteristics corresponding with one position of the head of the person who wears the headphones.

8. Sound reproducing system according to claim 6 or 7, characterized in that a head tracker is provided by means of which the position of the head of the person who wears the headphones can be determined.

9. Sound reproducing system according anyone of the claims 6-8, characterized in that the control means further comprise combination means and correction means to provide, in response to the microphone signals, for signals, which, supplied to the sound generating means, reduce unknown unwanted, particularly environmental noise signals, the transfer function of the correction means being such that the product of the latter transfer function with the transfer function of the sound generating means to the microphones is about 1 (one) over a certain frequency range.

10. Sound reproducing system according to anyone of the claims 6-9, characterized in that the control means further comprise combination means and further correction means to insert a further sound signal to the sound generating means and to correct

the microphone signal with a correction signal derived from said further audio input signal, the transfer function of the correction means substantially being the same as the transfer function of the sound generating means to the microphones.

11. Algorithm for processing the filter device in anyone of the claims 6-10 and applied in the method of anyone of the claims 1-5.

12. Audio apparatus, provided with the sound reproducing system according to anyone of the claims 6-10.

13. Computer program capable of running on signal processing means in an audio apparatus or cooperating with an audio apparatus comprising the sound reproducing system according to anyone of the claims 6-10.

14. Information carrier, carrying instructions to be executed by signal processing means, the instructions being such as to enable said signal processing means to perform the method according to anyone of the claims 1-5.

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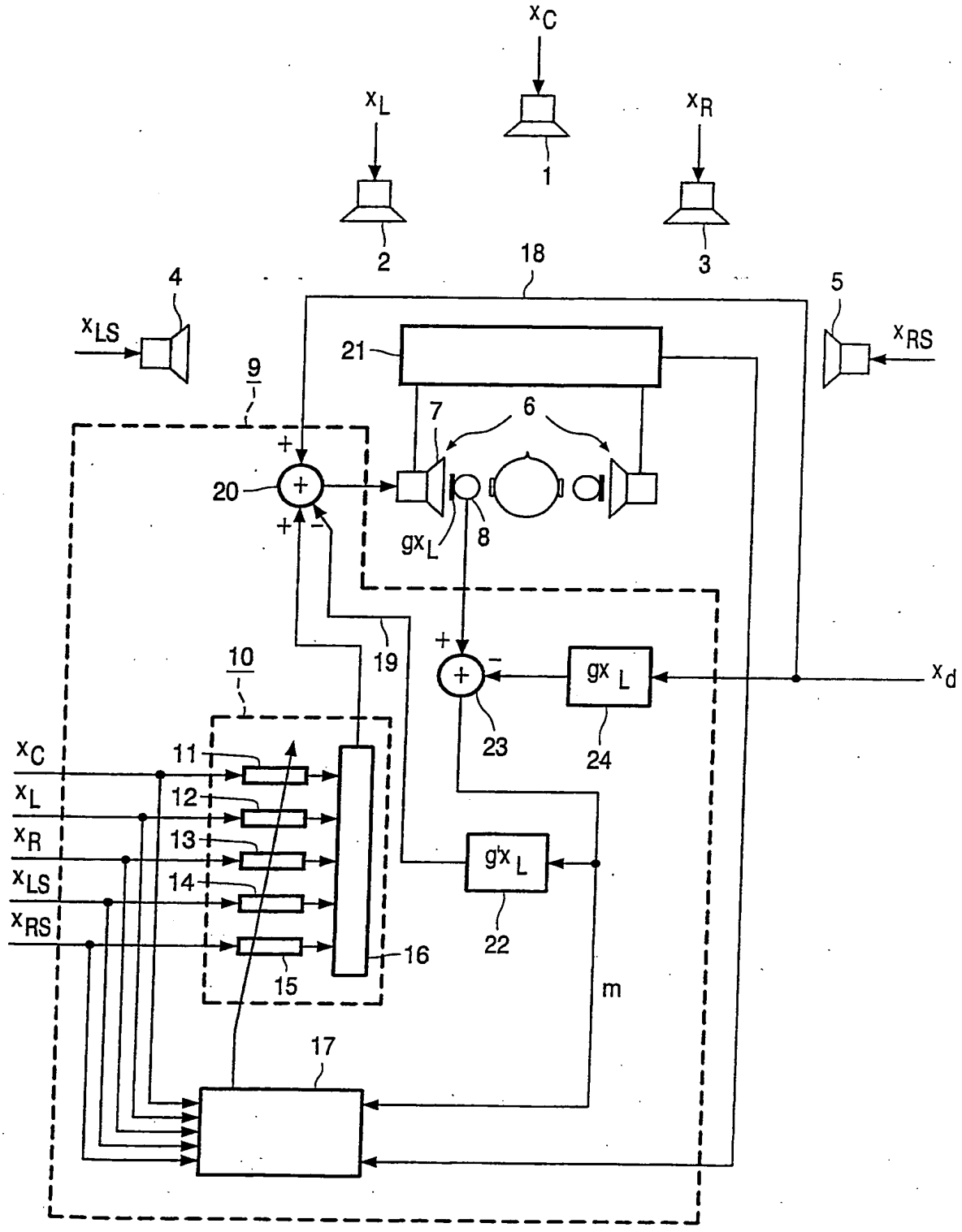
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INTERNATIONAL SEARCH REPORT

In tional Application No
PCT/IB 02/03728

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G10K11/178

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G10K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 078 672 A (VAUDREY MICHAEL ALLEN ET AL) 20 June 2000 (2000-06-20) column 1, line 4 - line 10; claim 1	1,6, 11-13
Y	US 5 937 070 A (CLIFTON SCOTT ET AL) 10 August 1999 (1999-08-10) column 1, line 15 - line 35 column 9, line 35 - line 41 column 11, line 18 -column 12, line 16	1,4-6, 11-14
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Lorne, B

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INTERNATIONAL SEARCH REPORT

Ir itional Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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